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Joint Institute for Nuclear Research Data Analysis Guide - Berkelium Edition

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JINR Data Analysis Guide

Bk Edition

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CMELS

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This is a data analysis guide to the JINR system developed by Roger Henderson. It is intended as a complete guide to the data format and the calibration parameters utilized for the analysis of the data. This guide will provide the basic structure of the data files, the description of the individual data items, and the basic equations developed for the calculation of the results. Currently (7/17/2009), calculation of the calibration parameters is not a covered topic. It is intended that this will be covered in a future update.

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Data Generation:

Experiments carried out at the Dubna Gas Filled Recoil Separator (DGFRS) utilize a detection system consisting of the following elements: Two multi-wire chambers serving as a time-of-flight detector as the entrance to the detector system; A series of 12 focal-plane position-sensitive planar ion-implanted silicon detector (PIPS) strips; a surrounding "box" of 8 PIPS strips, without position sensitivity; and finally a back-plane set of three PIPS strips which serve as veto detectors for the system. There are multiple sets of electronics for amplification of the detector signals, permitting, in the case of the focal-plane detectors, both particle and position sensitivity. Separate channels are maintained for alpha spectra, fission spectra, alpha positions, and fission positions. The side detectors maintain separate channels for alpha and fission spectra.

The system is managed by up to three analog-to-digital converters (ADCs), with the third one perhaps primarily utilized for other experiments. Calibration parameters are provided, so it will be discussed. The primary ADC is backed up by a fast ADC which is triggered during the primary ADC's deadtime, should a fast event come in. The third ADC is similar to the primary ADC.

Data is written into storage buffers prior to writing the data to the output file. The main storage buffer contains 256 16-word events from the primary ADC. The secondary storage buffer contains 32 5-word reads from the second ADC. When either buffer fills, the data is written to the output file in a block consisting of the 256 main events followed by the 32 fast events. The data is written in a form read as integer*2 variables using Fortran.

Data Description:

Table 1 displays the data format for the JINR heavy element experiments.

Word	Parameter	Description
1	α-particle and EVR channel # for the focal-plane detectors.	2048 channel spectra are recorded from 12 strips.
2	α-particle and SF channel # for the side detectors.	2048 channel spectra are recorded from 8 strips.
3	α-particle and EVR position channel # for the focal-plane detectors.	2048 channel spectra are recorded from 12 strips.
4	Fission position channel # for the focal-plane detectors.	2048 channel spectra are recorded from 12 strips.
5	Fission channel # for the focal-plane detectors.	1024 channel spectra are recorded from 3 strip bundles, 4 detectors per bundle.
6	Back-plane detector channel #.	1024 channel spectra are recorded from 3 strip bundles.
7	Counter	Used to properly align the events from the fast ADC with the primary ADC data.
8	Time of Flight channel #.	High gain signal, which may not be used in these experiments.
9	Fission channel # for the side detectors. – Not used for this experiment.	1024 channel spectrum taken for all of the side detectors combined.

Word	Parameter	Description
10	Time of Flight channel #.	Low gain signal, which appears to be the only signal utilized in the JINR developed analysis code.
11	Empty	
12	High-order time word.	Elapsed time from the start of the run in 0.1 ms.
13	Low-order time word.	Elapsed time from the start of the run in 0.1 ms.
14	Beam time signal.	Elapsed time from the start of the beam in μs.
15	Status Word.	Bit 1 indicates if the beam was off (0) or on (1). Bit 2 indicates noise during the read (0) for no, (1) for yes. Bit 5 identifies the gas chamber (0) for no, (1) for yes.
16	ADC identifier.	Word(16) ≠ 0 or ≠ 111 indicates ADC 1. Word(16) = 0 indicates ADC 2. Word(16) = 111 indicates ADC 3.
Fast ADC (2) data reads:		
1	α-particle channel # for the focal-plane detectors.	2048 channel spectra are recorded from 12 strips.
2	α-particle position channel # for the focal-plane detectors.	2048 channel spectra are recorded from 12 strips.
3	Side detector channel #.	1024 channel spectra are recorded from 8 strips.
4	Elapsed time from EVR.	Time in μs.
5	Counter.	Coincides with Word(7) to properly place the event.

The following are the JINR equations in a mathematics (not programming) form. They are derived from z2npca.f, which is a program written to produce a number of data plots. The variables used are the same ones found in the JINR code. They are defined along with the required Fortran format necessary for the calculations.

Alpha event calculations:

Variable	Storage	Comment
WORD(#)	Integer*2	Ranges to 24576 (12*2048)
DETID	Integer*2	Must be 1 – 12 for a valid event
CHANLO	Integer*2	Ranges from 0 – 2048 for a valid event
DETIW	Integer*2	Must be 1 – 8 for a valid event
CHANLW	Integer*2	Must be 0 – 2048 for a valid event
POST	Integer*2	Must be 0 – 2047 for a valid event, otherwise it is set to 0.

Events are written from the detector arrays, 12 for the focal plane and 8 for the side channels, by offsetting each detector's output by multiplying 2048 by the detector number minus one and adding that to the detected channel number. Thus the entire array of detectors can be stored in a single data word.

$DETID = INT\left(\frac{FLOAT(WORD(1))}{2048.}\right) + 1$ - from the focal plane detectors

$CHANLO = WORD(1) - (DETID - 1) * 2048$ - from the focal plane detectors

$DETIW = INT\left(\frac{FLOAT(WORD(2))}{2048.}\right) + 1$ - from the side detectors

$CHANLW = WORD(2) - (DETIW - 1) * 2048$ - from the side detectors

$$POST = WORD(3) - (DETID - 1) * 2048$$

If POST < 0 or POST > 2047, then POST = 0. The focal plane detectors are the only ones with position sensitivity.

These are the initial data statements to begin the process.

FISIND

FISIND is a trigger variable for fissions. FISIND = 0 for alpha and EVR events. This is the default value. If CHANHI ≠ 0 or POSFT ≠ 0, then FISIND = 1. These variables are introduced in the fission section. FISIND = 2 for a fast (ADC 2, WORD(16) = 0) event and CHANLO (the alpha channel) = 2047.

If FISIND = 0 and valid POST (0 ≤ POST ≤ 2048) and valid CHANLO (0 ≤ CHANLO < 2047) then calculate:

$ENERGY = ECALL1(DETID) * CHANLO + ECALL0(DETID)$, which has the units of keV.

$$POSITN = ECLAT1(DETID) * POST + ECLAT0(DETID)$$

There are two sets of parameters (1,0 : 3,2) for the coefficients listed above, depending upon ADC ≠ 2, or ADC = 2.

$$POSENR = \frac{POSITN}{ENERGY}$$

If 0.15 < POSENR < 1.15 then

$PSTN = INT(ECLATC(DETID) * (1 - POSENR))$, which has the units of 0.01 mm.

If FISIND = 0 then calculate the following:

$$ENER = INT(ECALL1(DETID) * CHANLO + ECALL0(DETID))$$

This is the same as was done above with ENERGY, but at this point in the program all three ADC's have separate coefficients listed. Also note that this is an integer variable. While it is not required to define this as an integer, some very minor differences due to rounding errors can be created when comparing data that is not defined as an integer variable. There are three sets of parameters (1,0 : 3,2 : 5,4) for the coefficients listed above.

$$ENER = INT\left(\frac{ENER - ECLD(DETID) * (PSTN - 2000)}{1 + ECLC(DETID) * (PSTN - 2000)}\right)$$

This is for the position sensitive detectors only. The side detectors do not require this treatment. There are two sets of parameters (ECLO and ECLS being the other pair) for the coefficients listed above, for ADC 1 or 2. Notice that there is no term for the Fast ADC (3) (Word(16) = 111). As of the writing of this document, it is interesting to note that ECLD and ECLO are both set to 0, and ECLC and ECLS are quite small, on the order of 10^{-5}.

$$ENEW = INT(ECALW1(DETIW) * CHANLW + ECALW0(DETIW))$$

This is for the side detectors. There can be up to three sets of parameters (1,0 : 3,2 : 5,4) for the coefficient listed above, for ADCs 1, 2, or 3.

$$ENERGY = FLOAT(ENER) + FLOAT(ENEW)$$

$ESUM = ENEW + ENER$ - For 0 < ENERGY < 32000, an integer value.

The following appears under the heading $\alpha \rightarrow \alpha$ or fission fragment:

$DELPOS = PSTN - PSATN(IALNXT)$ - For FISIND = 0

$DELPOS = PSTN - PSATN(IALNXT) - ZDF(DETID) + ZDA(DETID)$ - For FISIND = 1

DELPOS compares the current position (PSTN) to that of a previous alpha decay position stored in the PSATN array.

For ZDA there is a second variable ZD2 corresponding to the second ADC. ZDA and ZD2 are applied if ENERGY is > 9800 keV. For ENERGY < 9800 there are a pair of corrections applied, ZDE1 and ZDE2, based on the focal plane energy deposition (ENER) being < 3000 keV (ZDE1) or > 3000 keV (ZDE2).

The JINR program that the equations were taken from is set up to search a stored matrix of values to find the immediately preceding alpha particle from the same detector. The program searches from the last entered value backwards in the matrix to determine if there is a correlation with the preceding stored data from the detector of interest. Criteria are set up and DELPOS is used as the comparison variable to determine if the position difference is within the specified window.

Fissions:

Variable	Storage	Comment
CHANHI	Integer*2	Ranges from 0 – 1023 for a valid event
CHANW	Integer*2	Ranges from 0 – 2048 for a valid event
POSFT	Integer*2	Must be 0 – 2047 for a valid event

$$DETID = INT\left(\frac{FLOAT(WORD(4))}{2048.}\right) + 1$$

$$CHANHI = WORD(5) - INT\left(\frac{FLOAT(DETID - 1)}{4.}\right) * 1024$$

If CHANHI < 0 or CHANHI > 1023 then CHANHI = 0. The fission energy channel information is stored as a combined signal from the four strips in a single detector element, unlike the alpha energy channel, where each individual strip within a detector element is recorded separately.

$CHANHW = CHANLW$ - as defined above in the alpha section.

This is a change from previous experiments, where this came from word(9). The ADC for word(2) has been increased to 2048 channels with an upper limit of 60 – 70 MeV. When there is low energy deposition in a focal plane detector with a coincident side event, then this is used with the alpha calibration coefficients. If there is a large energy deposition in the focal plane detectors, indicative of a fission event, then this is used with the fission calibration coefficients.

$$POSFT = WORD(4) - (DETID - 1) * 2048$$

These are the initial data statements to begin the process.

If FISIND = 1 and valid POSFT (0-2047) and valid CHANHI (0-1023) then calculate the following:

$$ENERGY = ECALH1(DETID) * CHANHI + ECALH0(DETID)$$

$$POSITN = ECLFT1(DETID) * POSFT + ECLFT0(DETID)$$

These are independent of the ADC!!

$$POSENR = \frac{POSITN}{ENERGY}$$

If 0.15 < POSENR < 1.15 then

$$PSFTN = INT(ECLATC(DETID) * (1 - POSENR))$$

Note that this is the same coefficient (ECLATC) used in the α and EVR channels above.

If FISIND = 2 then PSTN=POST, note that POST is a channel number!

If POSFT > 0 then

$$PSFTN = PSFTN - INT(FLOAT(PSFTN) * BFP(DETID) + AFP(DETID))$$

Store PSTN = PSFTN. PSTN is used as the primary output variable in the remainder of the program.

Again, note that these equations are independent of the ADC!

$$ENER = INT((ECALHI1(DETID) * FLOAT(CHANHI) + ECALH0(DETID)) * Z48(DETID))$$

If PSFTN ≠ 0 then

$$ENER = INT\left(\frac{\left(FLOAT(ENER) - \frac{ECLD(DETID)}{100.} * (FLOAT(PSTN) - 2000.)\right)}{1. + ECLC(DETID) * (FLOAT(PSTN) - 2000.)}\right)$$

If there is a valid side fission channel then

$$ENEW = INT(ECAHW1(DETIW) * FLOAT(CHANHW) + ECAHW0(DETIW))$$

$$ENERGY = FLOAT(ENER) + FLOAT(ENEW)$$

$ESUM = ENER + ENEW$ - if 0 < ENERGY < 32000

If FISIND = 2 then:
ENER = CHANLO
ENEW = CHANLW
ESUM = 2222

Evaporation Residues (EVRs):

EVRs are in a simplistic sense just alpha events with a corresponding time of flight (TOF) signal. The equations shown are exactly the same as in the alpha event section.

$$DETID = INT\left(\frac{FLOAT(WORD(1))}{2048.}\right)+1$$

$$CHANLO = WORD(1)-(DETID-1)*2048$$

$$POST = WORD(3)-(DETID-1)*2048$$ - If POST < 0 or POST > 2047, then POST = 0

If FISIND = 0 and valid POST and valid CHANLO then calculate:

$$ENERGY = ECALL1(DETID)*CHANLO + ECALL0(DETID)$$

$$POSITN = ECLAT1(DETID)*POST + ECLAT0(DETID)$$

There are two sets of parameters (1,0 : 3,2) for the coefficients listed above, depending upon ADC ≠ 2, or ADC = 2.

$$POSENR = \frac{POSITN}{ENERGY}$$

If 0.15 < POSENR < 1.15 then

$$PSTN = INT(ECLATC(DETID)*(1-POSENR))$$

If FISIND = 0 then calculate the following:

$$ENER = INT(ECALL1(DETID)*CHANLO + ECALLO(DETID))$$

There are up to three sets of parameters (1,0 : 3,2 : 5,4) for the coefficients listed above. Not all of them are used in these experiments.

$$ENER = INT\left(\frac{ENER - ECLD(DETID)*(PSTN-2000)}{1+ECLC(DETID)*(PSTN-2000)}\right)$$

This is for the position sensitive detectors only. The side detectors do not require this treatment. There are two sets of parameters for the coefficients listed above, for ADC 1 or 2. Notice that there is no term for the Fast ADC (3) (Word(16) = 111).

Position adjustment for EVR's only:

$$PSTN = PSTN + INT(FLOAT(PSTN)*BRP(DETID) + ARP(DETID))$$

The following is under a section titled EVR → Alpha particle or fission fragment: Focal plane alpha energy must be between 9.8 and 12 MeV.

$DELPOS = PSTN - PSRTN(IERNXT) - ZDA(DETID)$ - For FISIND = 0 and ADC ≠ 2.

$DELPOS = PSTN - PSRTN(IERNXT) - ZD2(DETID)$ - For FISIND = 0 and ADC = 2.

$DELPOS = PSTN - PSRTN(IERNXT) - ZDF(DETID)$ - For FISIND = 1.

$DELPOS = 0$ - For FISIND = 2.

Here the current event position PSTN is being compared to the stored matrix of EVR positions, PSRTN. The corrections noted bring the two events into the same basis. DELPOS is then used in logic functions to determine if there is a correlation between the current event and the stored event. The detector IDs are compared, and the last stored event with the same detector is used for the comparison in this program.

$DTC1 = \frac{11400. - FLOAT(ENER)}{1000.}$ - This is used in a logic statement involving 9900 < ENER < 11400

The following is under a heading EVR → Alpha (side), and is only applicable for focal plane alpha events with energy less than 9.8 MeV.

$DELPOS = PSTN - PSRTN(IERNXT) - ZDE1(DETID)$ - For FISIND = 0, ENEW > 0, 0 < ENER < 3000, and ADC ≠ 2.

$DELPOS = PSTN - PSRTN(IERNXT) - ZDE2(DETID)$ - For FISIND = 0, ENEW > 0, ENER ≥ 3000, and ADC ≠ 2.

$DELPOS = PSTN - PSRTN(IERNXT) - ZDE3(DETID)$ - For FISIND = 0, ENEW > 0, 0 < ENER < 3000, and ADC = 2.

$DELPOS = PSTN - PSRTN(IERNXT) - ZDE4(DETID)$ - For FISIND = 0, ENEW > 0, ENER ≥ 3000, and ADC = 2.

Calculation Notes:

Instant event rejection:

If WORD(1) < 0 or WORD(1) > 24576
If WORD(2) < 0 of WORD(2) > 24576
If WORD(3) < 0 or WORD(3) > 24576
If WORD(1) = 0 and WORD(2) = 0 and WORD(3) = 0

After initial event calc, we have a new round of event rejection:

If CHANLO = 0 and CHANHI = 0 and CHANLW = 0
If CHANLO ≠ 0 and (DETID < 1 or > 12)
If CHANHI ≠ 0 and (DETID < 1 or > 12)

General Considerations:

The signal from the back detectors, WORD(6), is used as evidence that a particle has punched through the focal plane detectors. The corresponding event written can then in general be disposed of. However, Vladimir has set up an entire set of conditions that vary per data file indicating that there are effectively discriminator levels that can be used to set the back detector channel to zero if there is data below a virtual low-level discriminator.

Fission events that occur with a corresponding TOF signal are generally rejected. If the total fission energy is greater than 170 MeV, then the events with a TOF signal are written to an output file, then the program goes and processes the next event. Fission events without an associated TOF signal are ignored if the total energy is below 120 MeV.

The read-out noise, bit 2 of word(15) is used as an event rejection item.

Bits from WORD(15) can be stripped out as follows:

$$BIT1 = IAND(WORD(15),'1'O)$$
$$BIT2 = ISHFT(IAND(WORD(15),'2'O),-1)$$
$$BIT5 = ISHFT(IAND(WORD(15),'20'O),-4)$$

Time Calculations:

Variable	Storage	Comment
NEWTIM	Real*8	

Event Time:

IF Word(12) < 0 then

$$NEWTIM = 6553.6 * DFLOAT(WORD(12) + 65536) + 0.1 * DFLOAT(WORD(13))$$

If Word(13) < 0 then

$$NEWTIM = NEWTIM + 6553.6$$

ELSE

$$NEWTIM = 6553.6 * DFLOAT(WORD(12)) + 0.1 * DFLOAT(WORD(13))$$

If Word(13) < 0 then

$$NEWTIM = NEWTIM + 6553.6$$

ENDIF

Time of Flight:

TOF = Word(10) – It appears that WORD(8) is not being used in this experiment.

Final Unit Conversion:

Alpha and EVR events are calculated in units of keV. Fissions are calculated in units of 0.1 MeV. Position data are calculated in units of 0.01 mm.